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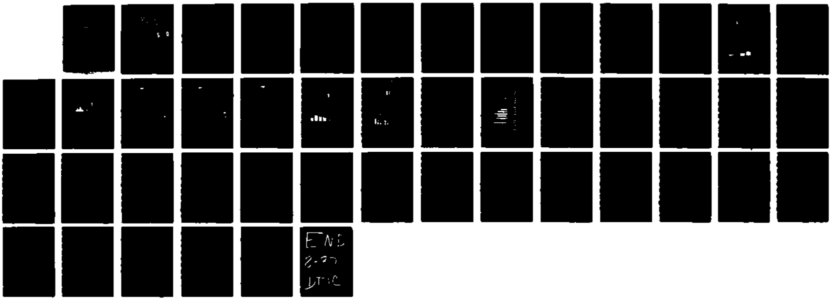

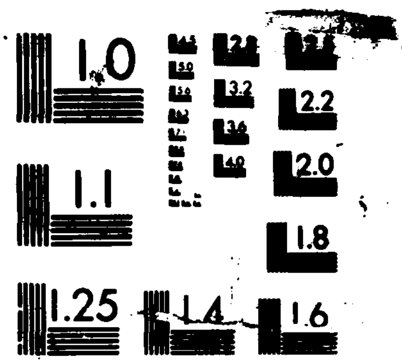

MICROCOPY RESOLUTION TEST CHART

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DOT/FAA/CT-86/42

FAA TECHNICAL CENTER
Atlantic City International Airport
N.J. 08405

AD-A181 930

Statistics on Aircraft Gas Turbine Engine Rotor Failures that Occurred in U.S. Commercial Aviation During 1981

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Naval Air Propulsion Center
Trenton, New Jersey

March 1987

Final Report

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16. Abstract

This report presents statistical information relating to gas turbine engine rotor failures which occurred during 1981 in commercial aviation service use. The predominant failure involved blade fragments, 83 percent of which were contained. Three disk failures occurred and all were uncontained. Fifty-seven percent of the 136 failures occurred during the takeoff and climb stages of flight.

This service data analysis is prepared on a calendar year basis and published yearly. The data is useful in support of flight safety analysis, proposed regulatory actions, certification standards and cost benefit analysis. Keywords

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- New England Region, Burlington, MA for providing verification of the uncontained engine rotor failure occurances during calendar year 1981.
- Flight Standards National Field Office, Oklahoma City, OK, for providing the basic data used to prepare this report.

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EXECUTIVE SUMMARY

This service data analysis is prepared on a calendar basis and published yearly. The data are useful in support of flight safety analyses, proposed regulatory actions, certification standards and cost benefit analyses. The following statistics are based on gas turbine engine rotor failures that have occurred in U.S. commercial aviation during 1981.

One hundred and thirty-six rotor failures occurred in 1981. These failures accounted for approximately 2.7 percent of the 5095 shutdowns experienced by the U.S. commercial fleet. Rotor fragments were generated in 84 of the failures and, of these 16 were uncontained. This represents an uncontained failure rate of 2.1 per million gas turbine engine powered aircraft flight hours, or 0.8 per million engine operating hours. Approximately 7.5 million and 20.7 million aircraft flight and engine operating hours, respectively, were logged in 1981.

Turbine rotor fragment producing failures were approximately four times greater than that of the compressor rotor fragment producing failures; 62 and 15 respectively, of the total. Fan rotor failures accounted for 7 of the fragment producing failures experienced.

Blade failures were generated in 78 of the rotor failures; 13 of these were uncontained. The remaining 6 fragment generating failures were produced by disk, rim, or seal.

Total uncontained engine failure rates per million engine type flight hours were: turbofan 0.7 and turboprop 1.5. No uncontained rotor failures were reported for turboshaft and turbojet engines in 1981.

Of the 92 known causes of failures (because of the high percentage of unknown causes of rotor failures, the percentages were based on the total number of known causes), the causal factors were: (1) Secondary Causes 38 (41.3 percent); (2) Foreign Object Damage 35 (38.0 percent); (3) Design and Life Prediction Problems 16 (17.4 percent); and (4) Other 3 (3.3 percent). Seventy-eight (57.4 percent) of the 136 rotor failures occurred during the takeoff and climb stages of flight. Fifty-two (61.9 percent) of the 84 rotor fragment producing failures and 9 (56.3 percent) of the 16 uncontained rotor failures occurred during these same stages of flight.

CONCLUSION:

Although the incidence of engine rotor failures producing fragments has declined 20 percent (84 in 1981 compared to a 1975 through 1980 average of 105), the uncontained engine rotor failure rate has remained constant (16 in 1981 compared to a 1975 through 1980 average of 16).

INTRODUCTION

This report is sponsored by the Department of Transportation (DOT), Federal Aviation Administration (FAA), Technical Center, Engine/Fuel Safety Branch, located at the Atlantic City International Airport, New Jersey.

This service data analysis is prepared on a calendar year basis and published yearly. The data are useful in support of flight safety analyses, proposed regulatory actions, certification standards and cost benefit analyses.

The intent and purpose of this report is to present data as objectively as possible on rotor failure occurences in U. S. commercial aviation.

Presented in this report are statistics on gas turbine engine failures that have occurred in U. S. commercial aviation during 1981. These statistics are based on data complied from the Flight Standards Service Difficulty Reports that were published by the DOT, FAA. Independent cross checks to other accident data sources, such as the FAA New England Region Directorate, were made to substantiate the exact nature of an engine failure incident (i.e., contained or uncontained). The compiled data were analyzed to establish:

1. The incidence of rotor failures and the incidence of contained and uncontained rotor fragments; (An uncontained rotor failure is defined as a rotor failure that produces fragments which penetrate and escape the confines of the engine casing).

2. The distribution of rotor failures with respect to engine rotor components, i.e., fan, compressor or turbine rotors and their rotating attachments or appendages such as spacers and seals.

3. The type of rotor fragment (disk, rim or blade) typically generated at failure.

4. The cause of failure.

5. The engines involved by model (JT8D, JT9D, etc.) and by engine type (turbojet, turboshaft/turboprop, and turbofan).

6. The flight conditions at the time of failure.

7. Engine failure rate according to engine fleet hours.

RESULTS

1. The data used for analysis are contained in appendix A. The results of these analyses are shown in Figures 1 through 8.

a. Figure 1 shows that 136 rotor failures occured in 1981. These rotor failures accounted for approximately 2.7 percent of the 5095 shutdowns experienced by the gas turbine powered U. S. commercial aircraft fleet during 1981. Rotor fragments were generated in 84 of the failures experienced and, of these, 16 (19.0 percent of the fragment producing failures) were uncontained. This represents an uncontained failure rate of 2.1 per million gas turbine engine powered aircraft flight hours, or 0.8 per milion engine operating hours. Approximately 7.5 million and 20.7 million aircraft flight and engine operating hours, respectively, were logged by the U. S. commercial aviation fleet in 1981. Gas turbine engine fleet

operating hours according to the number and type of engines in use is shown in Figure 2.

b. Figure 3 shows the distribution of rotor failures that produced fragments according to the engine component involved (fan, compressor, turbine), the types of fragments that were generated, and the percentage of uncontained failures according to the type of fragment generated. These data indicate that:

(1) The incidence of turbine rotor fragment producing failures was approximately four times greater than that of the compressor rotor fragment producing failures; these corresponded to 62 (73.8 percent) and 15 (17.9 percent), respectively, of the total number of rotor failures. Fan rotor failures accounted for 7 (8.3 percent) of the fragment producing failures experienced.

(2) Blade fragments were generated in 78 (92.9 percent) of the rotor failures; 13 (16.7 percent) of these were uncontained. The remaining 6 (7.1 percent) rotor fragment failures were produced by disk, rim, or seal.

c. Figure 4 shows the rotor failure distribution among the engine models that were affected, and the total number of the models in use.

d. Figures 5, 6, and 7 illustrate engine failure rates per million engine flight hours according to engine model, engine type, and containment condition. The total engine failure rate per million engine type flight hours are: turbofan 5.7, turboprop 11.8, turboshaft 34.2, and turbojet 27.0. Total uncontained engine failure rates per million engine type flight hours were: turbofan 0.7 and turboprop 1.5. No uncontained rotor failures were reported for turboshaft and turbojet engines in 1981.

The data used to generate figures 5, 6, and 7 is contained in appendix B, page B-1.

e. Figure 8 shows what caused the rotor failures to occur. Of the 92 known causes of failure (because of the high percentage of unknown causes of rotor failure, the percentages were based on the total number of known causes), the causal factors were: (1) Secondary Causes 38 (41.3 percent); (2) Foreign Object Damage 35 (38.0 percent); (3) Design and Life Prediction Problems 16 (17.4 percent); and Other 3 (3.3 percent).

f. Figure 9 indicates the flight conditions that existed when the various rotor failures occurred. Seventy-eight (57.4 percent) of the 136 rotor failures occurred during the takeoff and climb stages of flight. Fifty-two (61.9 percent) of the rotor fragment producing failures and 9 (56.3 percent) of the uncontained rotor failures occurred during these same stages of flight. The highest number of uncontained rotor failures, 7 (43.8 percent) was experienced during climb.

g. Figure 10 is a cumulative tabulation that describes the distribution of uncontained rotor failures according to fragment type, engine component involved, cause category, and flight condition (takeoff and climb are defined as "high power," all other conditions are defined as "low power") for the years 1976 through 1981. This figure is expanded yearly to include all subsequent uncontained rotor failures. These data indicate that: for "secondary causes," the number of uncontained failures was approximately 8 times greater at "high" power than "low" power (namely 23 and 3). For "Design and Life Prediction Problems" the number of

"high" power uncontained failures was approximately three times greater than "low" power (namely 19 and 6); and for "Foreign Object Damage" the number of uncontained failures was six times greater at "high" power than "low" power (namely 6 and 1). This tabulation also indicates that of the 95 total uncontained incidences, blade failures accounted for 75.8 percent, disks failures 10.5 percent, rim failures 7.4 percent, and seal/spacer failures 6.3 percent.

h. Figure 11 shows the annual incidence of uncontained rotor failures in commercial aviation for the years 1962 through 1981. During 1981, the incidence of uncontained rotor failure increased by five over the previous year, 1980. Over the past six years, 1976 through 1981, an average of 16 uncontained rotor failures per year have occurred. During the same time period, the rate of uncontained rotor failures has remained relatively constant at an average of approximately one per million engine operating hours.

The high incidences of uncontained rotor failures in calendar years 1967 through 1973 (except for 1968) were probably due to the introduction of newly developed engines entering the commercial aviation fleet such as the JT9D and CF6 engines.

Structural life prediction and verification is being improved by the increased use of spin chamber testing by government and industry as a means of obtaining failure data for statistically significant samples. In addition, increased development and application of high sensitivity non-destructive inspection methods, should increase the probability of cracks being detected prior to failure. The capability to reduce the causes of failures from secondary effects, also is being addressed through technology development programs. However, causes due to foreign object damage still appear to be beyond the control or scope of present technology.

CONCLUSION

Although the incidence of engine rotor failures producing fragments has declined 20 percent (84 in 1981 compared to a 1975 through 1980 average of 105), the uncontained engine rotor failures has remained constant (16 in 1981 compared to a 1975 through 1980 average of 16).

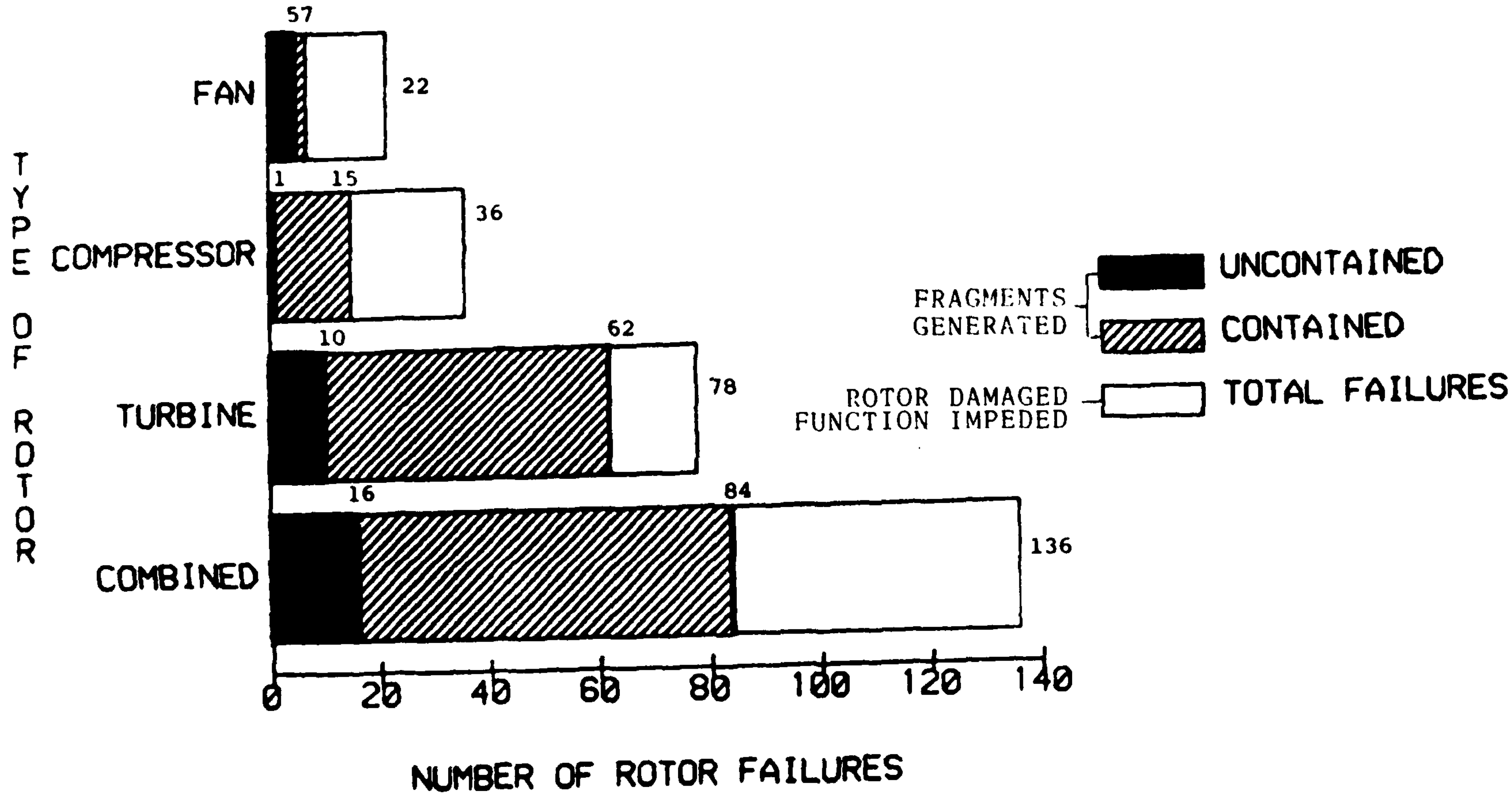
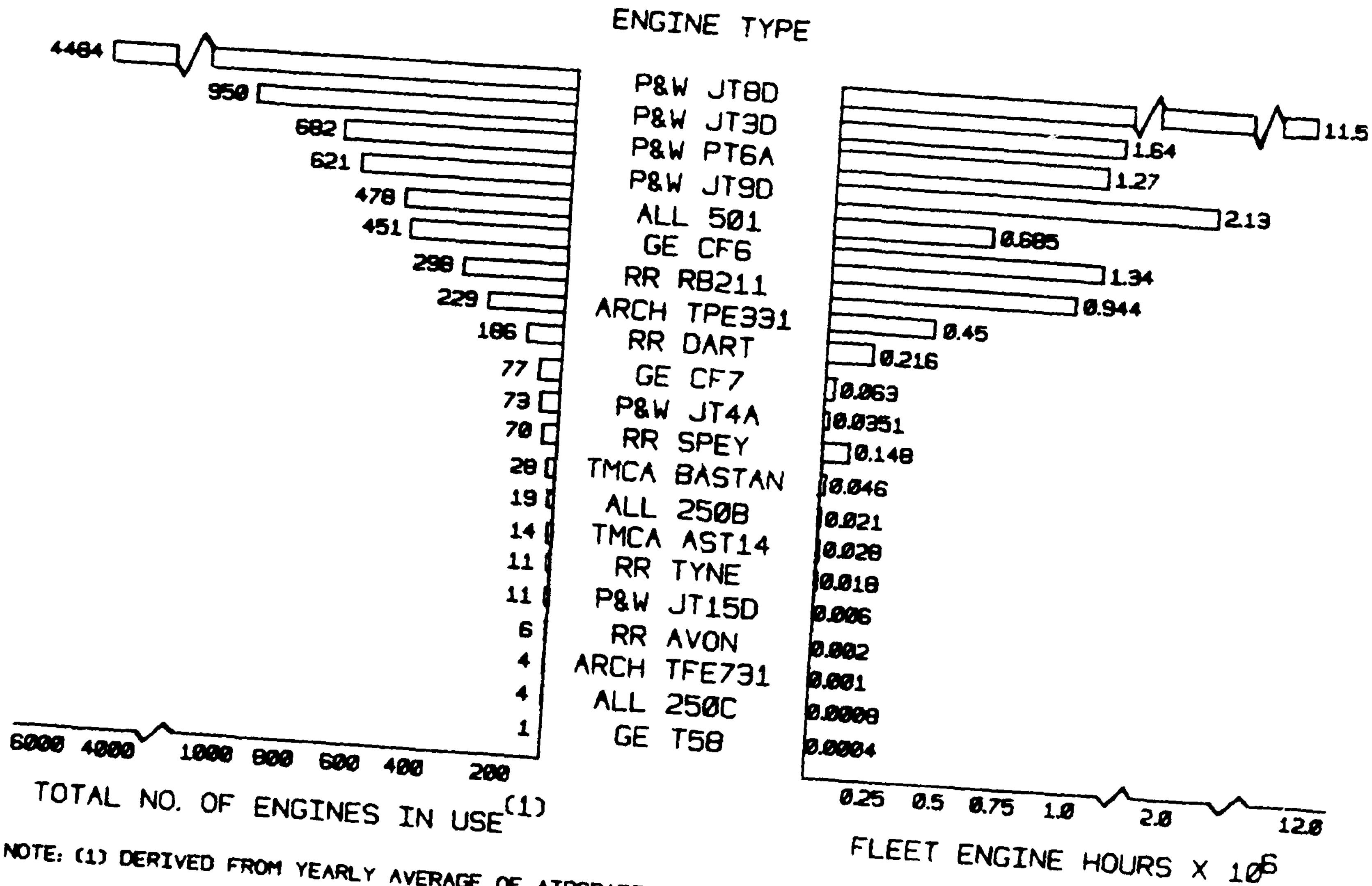


FIGURE 1: INCIDENCE OF ENGINE ROTOR FAILURE IN U. S. COMMERCIAL AVIATION 1981



NOTE: (1) DERIVED FROM YEARLY AVERAGE OF AIRCRAFT IN USE AT END OF EACH MONTH

FIGURE 2: GAS TURBINE ENGINE FLEET OPERATING HOURS IN U.S. COMMERCIAL AVIATION ACCORDING TO NUMBER OF ENGINES IN SERVICE - 1981

ENGINE ROTOR COMPONENT	TYPE OF FRAGMENT GENERATED									
	DISK		RIM		BLADE		SEAL		TOTAL	
	TF	UCF	TF	UCF	TF	UCF	TF	UCF	TF	UCF
FAN	0	0	0	0	7	5	0	0	7	5
COMPRESSOR	1	1	1	0	12	0	1	0	15	1
TURBINE	2	2	1	0	59	8	0	0	62	10
TOTAL	3	3	2	0	78	13	1	0	84	16

(1) FAILURES THAT PRODUCED FRAGMENTS

TF-TOTAL FAILURES
UCF-UNCONTAINED FAILURES

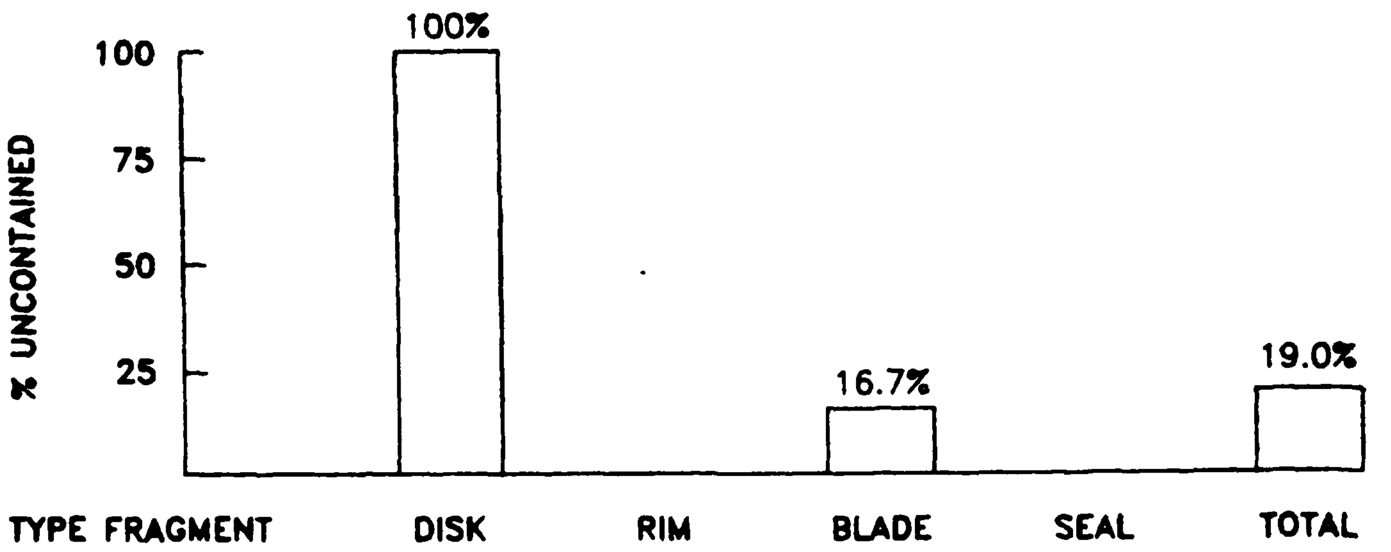
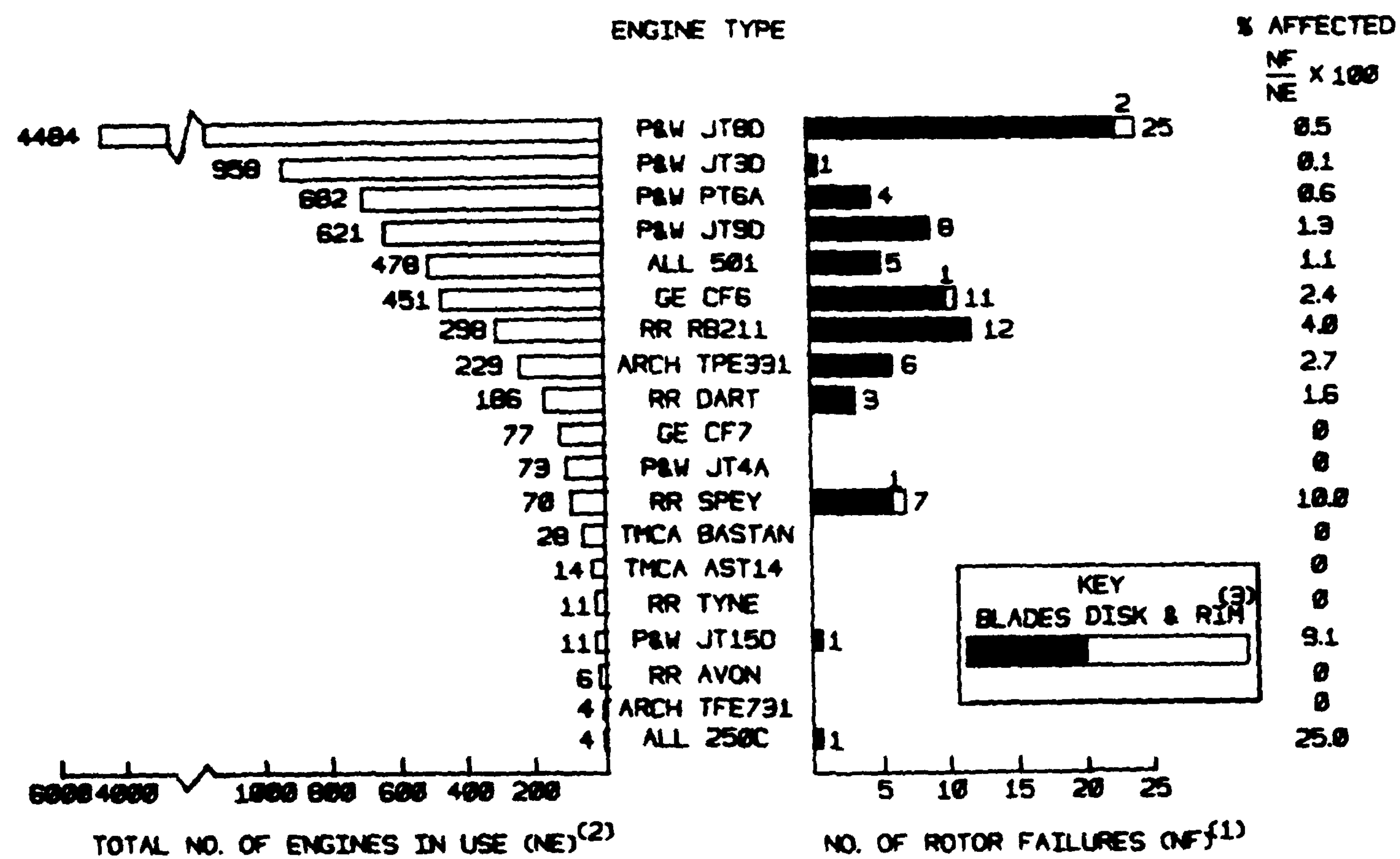
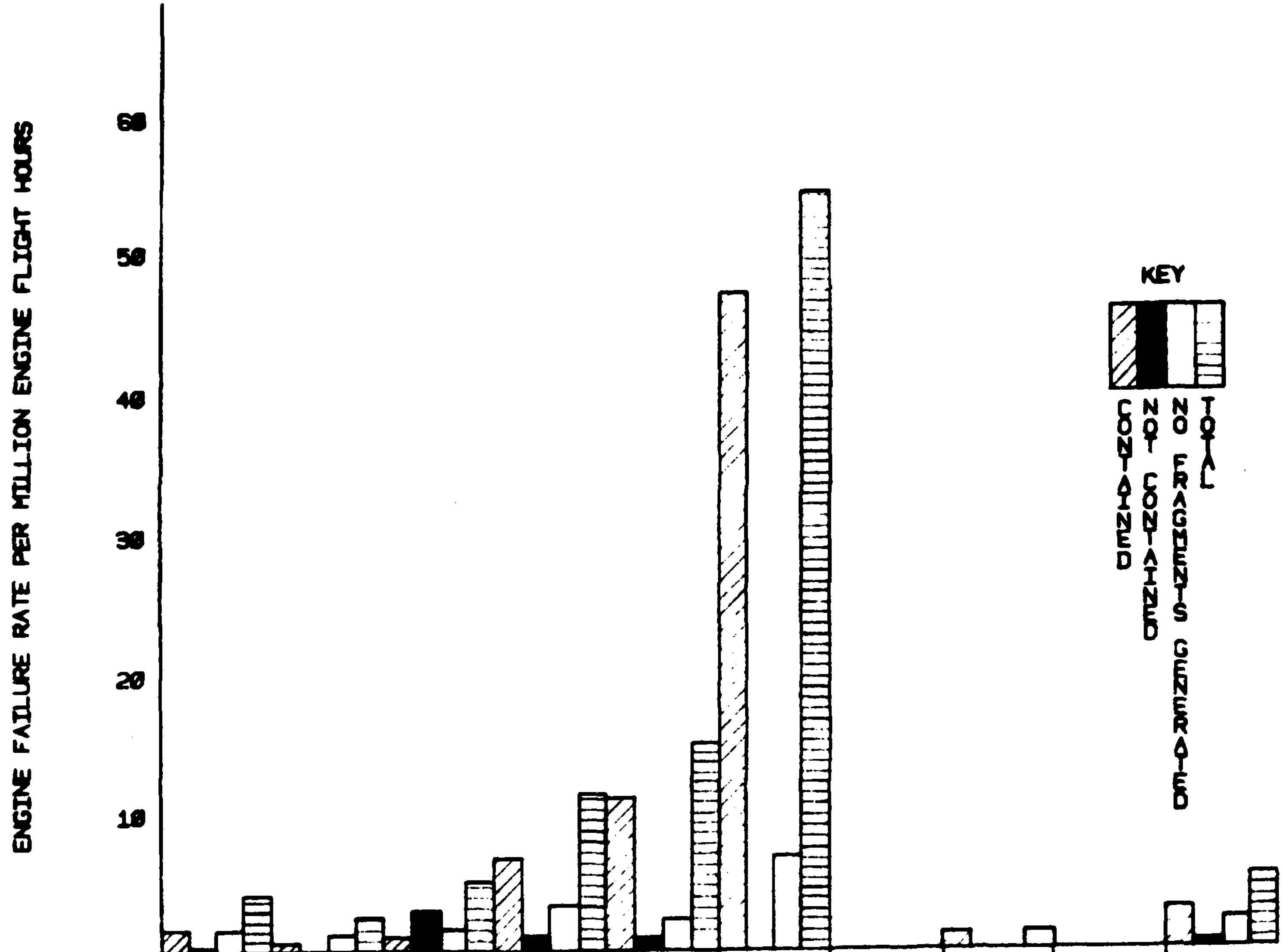


FIGURE 3: COMPONENT AND FRAGMENT TYPE DISTRIBUTIONS FOR CONTAINED AND UNCONTAINED ROTOR ENGINE FAILURES (FAILURES THAT PRODUCED FRAGMENTS) - 1981



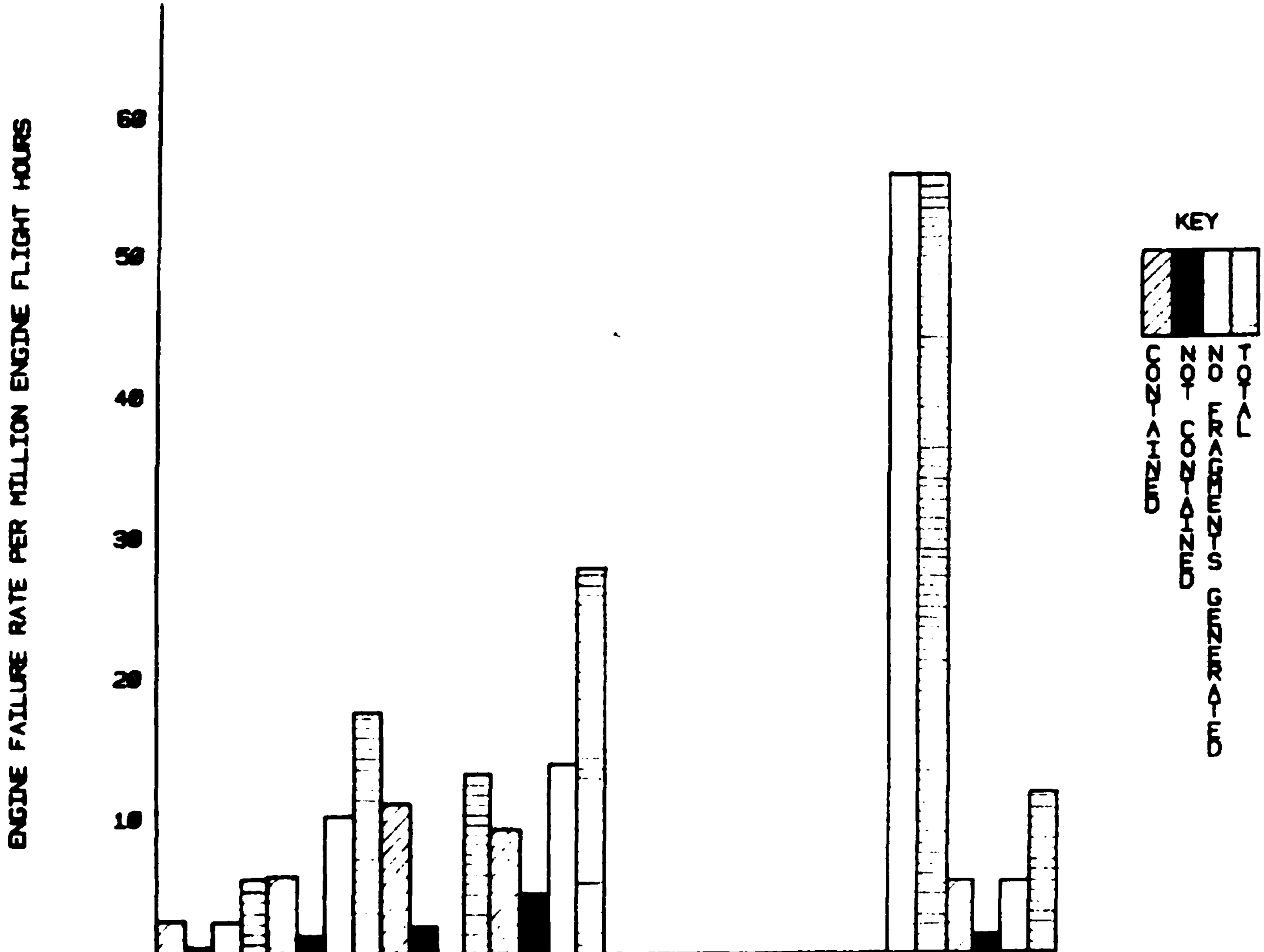
NOTES: (1) FAILURES THAT PRODUCED FRAGMENTS
(2) YEARLY AVG. OF ENGINES IN USE AT END OF EACH MONTH
(3) SEAL/SPACER FAILURES INCLUDED IN DISK/RIM COMPILATION

FIGURE 4: THE INCIDENCE OF ENGINE ROTOR FAILURE IN U.S. COMMERCIAL AVIATION ACCORDING TO ENGINE TYPE AFFECTED - 1981



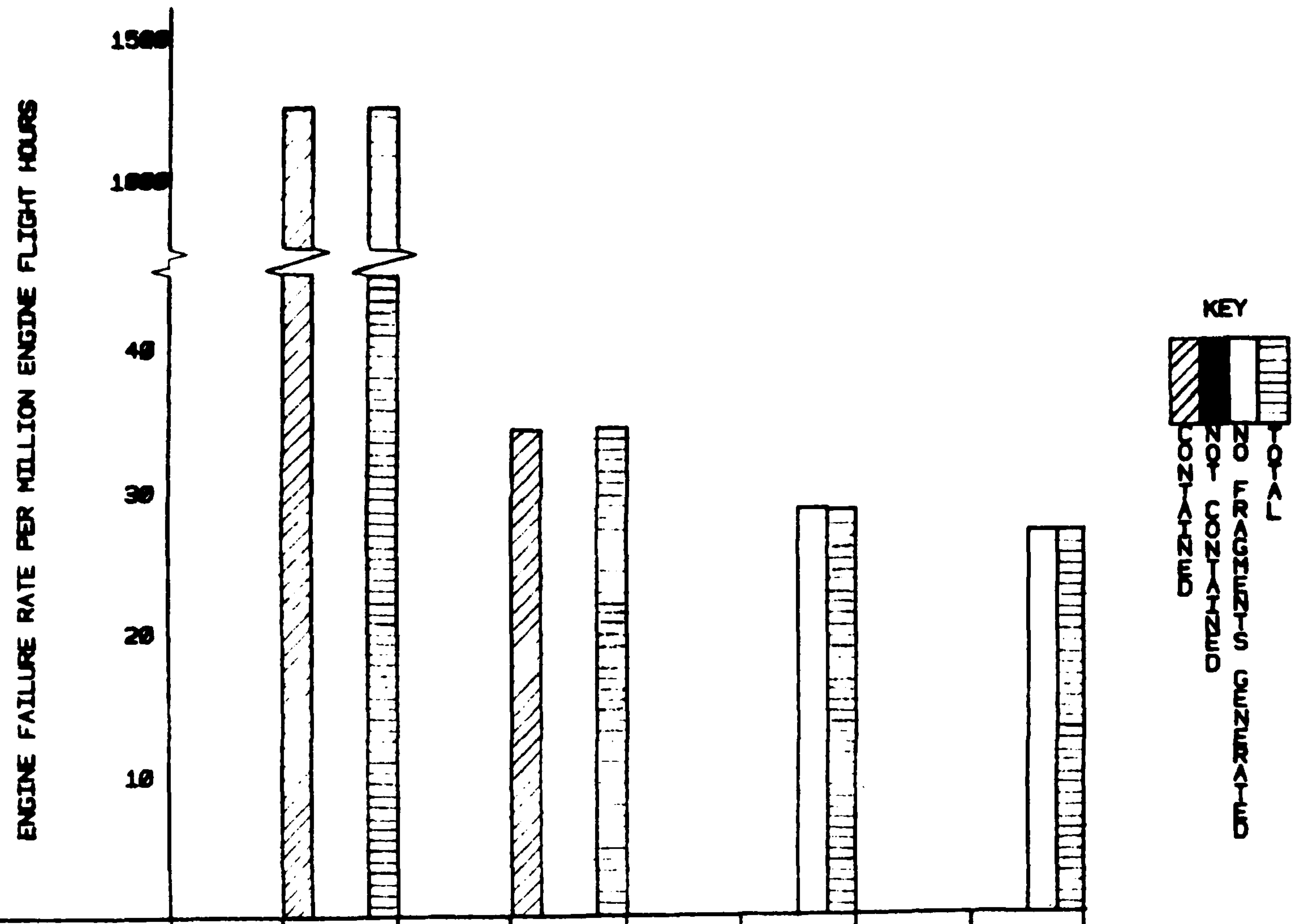
ENGINE MODEL	JT8D	JT3D	JT9D	CF6	RB211	SPEY	CF7	JT15D	TFE731	TOTAL
ENGINE FLIGHT HOURS X 10^6	11.5	1.64	2.13	1.34	0.944	0.148	0.063	0.006	0.001	17.77

FIGURE 5: TURBOFAN ENGINE FAILURE RATE ACCORDING TO ENGINE MODEL - 1981



ENGINE MODEL	PT6A	501	TPE331	DART	BASTAN	250B	TYNE	TOTAL
ENGINE FLIGHT HOURS X 10^6	1.27	0.685	0.45	0.216	0.046	0.021	0.018	2.706

FIGURE 6: TURBOPROP ENGINE FAILURE RATE ACCORDING TO ENGINE MODEL - 1981



ENGINE MODEL	AST14	250C	T58	TOTAL	JT4A	AVON	TOTAL
ENGINE FLIGHT HOURS X 10^6	0.028	0.0008	0.0004	0.0292	0.0351	0.002	0.0371
ENGINE TYPE	TURBOSHAFT				TURBOJET		

FIGURE 7: TURBOSHAFT AND TURBOJET ENGINE FAILURE RATE ACCORDING TO ENGINE MODEL - 1981

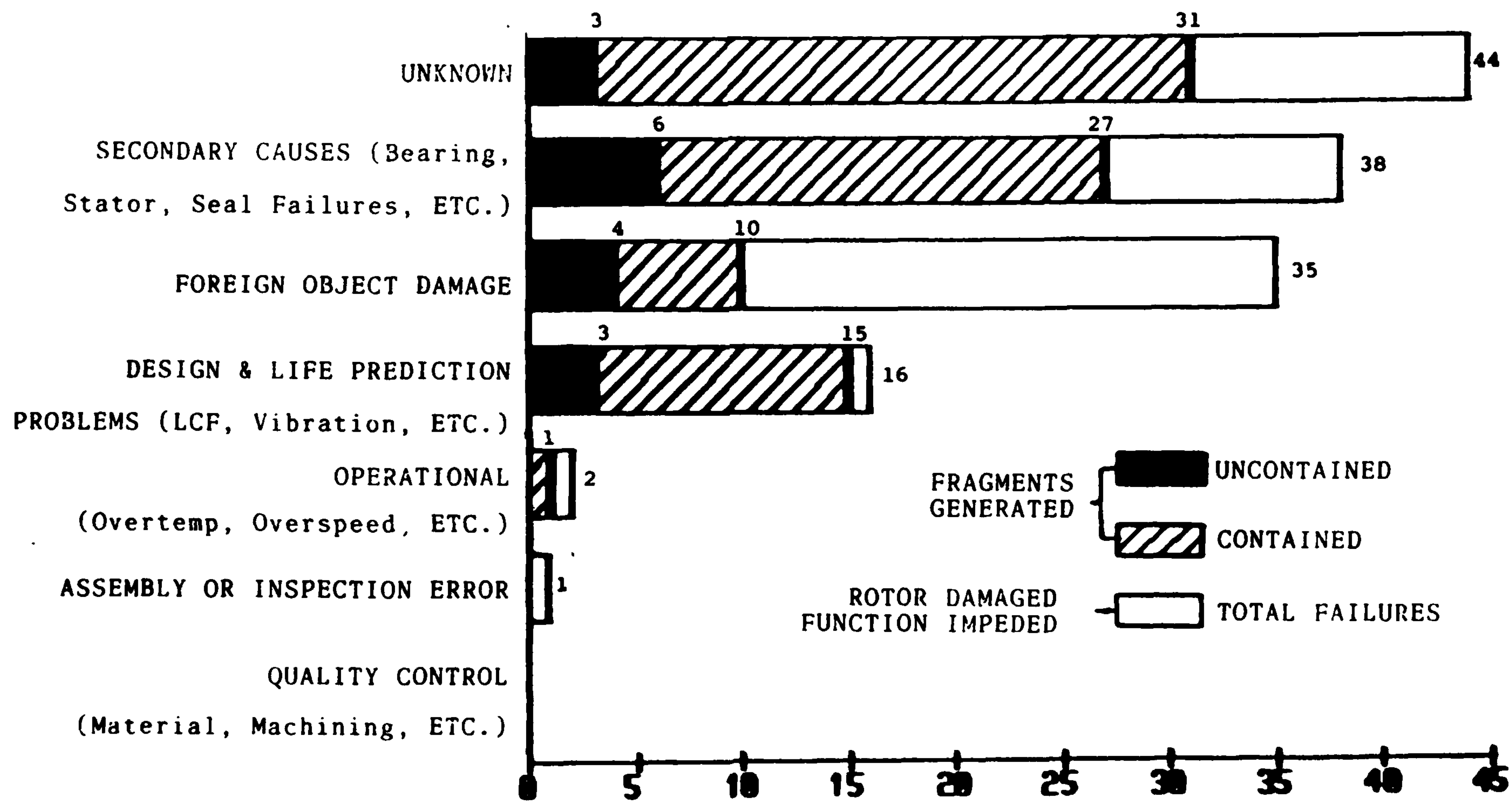


FIGURE 8: ENGINE ROTOR FAILURE CAUSE CATEGORIES - 1981

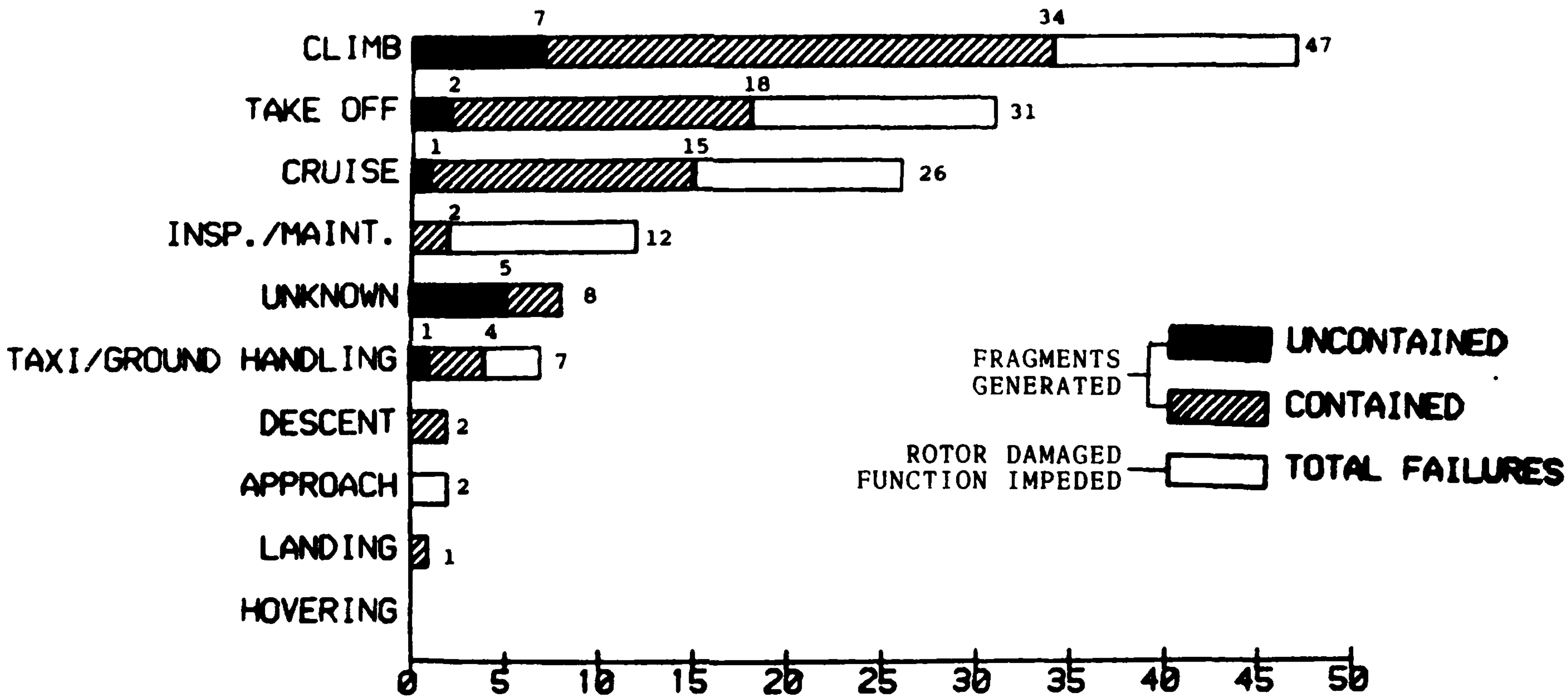


FIGURE 9: FLIGHT CONDITION AT ENGINE ROTOR FAILURE - 1981

TYPE OF FRAGMENT GENERATED	ENGINE ROTOR COMPONENT	DESIGN/LIFE PREDICTION PROBLEMS			SECONDARY CAUSES			FOREIGN OBJECT DAMAGE			QUALITY CONTROL			OPERATIONAL			ASSEMBLY/INSPECTION REPORTS			UNKNOWN			SUBTOTAL			TOTAL
FLIGHT CONDITION		HI	LOW	UNK	HI	LOW	UNK	HI	LOW	UNK	HI	LOW	UNK	HI	LOW	UNK	HI	LOW	UNK	HI	LOW	UNK	HI	LOW	UNK	
DISK	FAN																									10
	COM.	4									1									1			6			
	TUR.		3					1															1	3		
RIM	FAN																									7
	COM.	2																		3	1		5	1		
	TUR.										1												1			
BLADE	FAN	6	1		3			5	1	2	2									3		1	19	2	3	72
	COM.	5			3															7	1		15	1		
	TUR.	1	2		15	3	1													5	4	1	21	9	2	
SEAL	FAN																									6
	COM.	1																		1	1		2	1		
	TUR.				2															1			3			
SUBTOTAL		19	6	0	23	3	1	6	1	2	4	0	0	0	0	0	0	0	0	21	7	2	73	17	5	95
TOTAL		25			27			9			0			0			0			30			95			

(1) TAKE OFF AND CLIMB ARE DEFINED AS "HIGH POWER" AND ALL OTHER CONDITIONS ARE DEFINED AS "LOW POWER".

FIGURE 10: UNCONTAINED ENGINE ROTOR FAILURE DISTRIBUTIONS

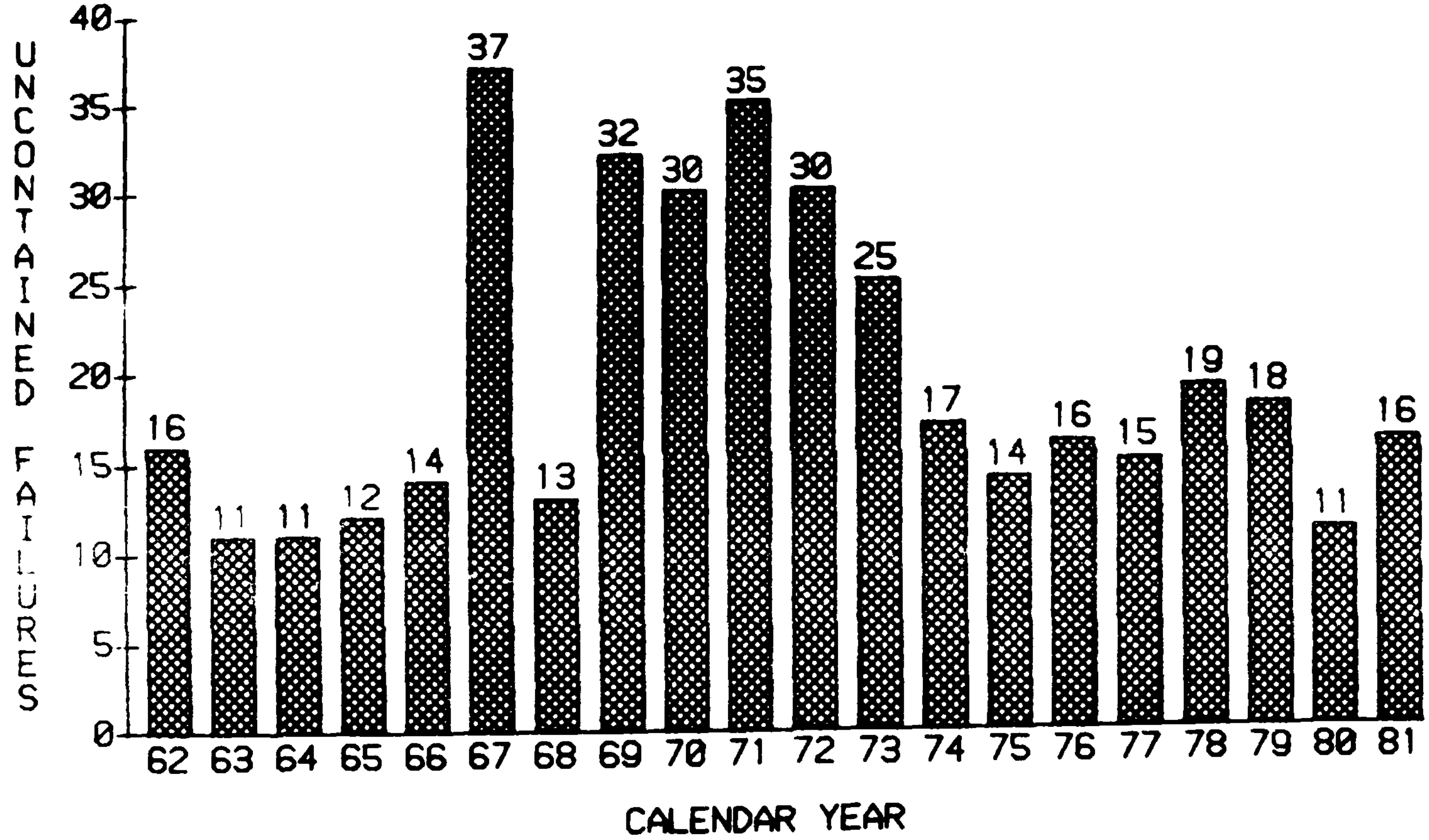


FIGURE 11: THE INCIDENCE OF UNCONTAINED ENGINE ROTOR FAILURE IN U.S. COMMERCIAL AVIATION 1962 - 1981

APPENDIX A

Data of Engine Rotor Failures in U. S. Commercial Aviation for 1981. Compiled from the Federal Aviation Administration Service Difficulty Reports.

DATA COMPILATION KEY

Component Code:
F - Fan
C - Compressor
T - Turbine

Fragment Type Code:
D - Disk
R - Rim
B - Blade
S - Seal
N - None

Cause Code:
1 - Design and Life Prediction Problems
2 - Secondary Causes
3 - Foreign Object Damage
4 - Quality Control
5 - Operational
6 - Assembly and Inspection Error
7 - Unknown

Containment Condition Code:
C - Contained
NC - Not Contained
N - No Fragments Generated

Flight Condition Code:
1 - Insp/Maint
2 - Taxi/Grnd Hdl
3 - Takeoff
4 - Climb
5 - Cruise
6 - Descent
7 - Approach
8 - Landing
9 - Hovering
10 - Unknown

CHARACTERISTICS OF ROTOR FAILURES - 1981

SDR NO.	SUBMITTER	AIRCRAFT	ENGINE	COMPONENT	FRAGMENT TYPE	CAUSE	CONTAINMENT CONDITION	FLIGHT CONDITION
03181036	EAL	B727	JT8D	F	N	3	N	5
06261020	ACL	B737	JT8D	F	N	3	N	4
07161032	PAA	B727	JT8D	F	N	2	N	4
01291032	AFL	B737	JT8D	F	N	3	N	1
09111032	OZA	DC9	JT8D	F	N	3	N	1
09171031	OZA	DC9	JT8D	F	N	3	N	3
02111037	EAL	B727	JT8D	C	N	3	N	3
03121037	ACL	B737	JT8D	C	N	3	N	3
05281025	USA	B727	JT8D	C	N	3	N	3
09211030	NWA	B727	JT8D	C	N	2	N	4
01151024	AFL	B737	JT8D	C	N	3	N	4
01261033	AAL	B737	JT8D	C	S	2	C	4
12071025	ACL	B737	JT8D	C	N	3	N	7
04241025	ACL	B737	JT8D	C	N	3	N	3
02131036	CAL	B727	JT8D	T	N	3	N	5
08141033	AFL	B737	JT8D	T	N	7	N	5
08211028	PSA	DC9	JT8D	T	N	7	N	1
08271024	PSA	DC9	JT8D	T	N	7	N	1
09041023	PSA	DC9	JT8D	T	N	7	N	1
09041024	PSA	DC9	JT8D	T	N	7	N	1
09041025	PSA	DC9	JT8D	T	N	7	N	1
03031036	ACL	B737	JT8D	T	N	7	N	3
11101024	FDE	B727	JT8D	T	N	2	N	4
09251030	AFL	DC9	JT8D	F	B	3	C	6
10091030	EAL	DC9	JT8D	C	D	1	NC	4
12181024	HAL	DC9	JT8D	C	B	1	C	3
02121039	AAL	B727	JT8D	T	B	2	C	5
02181033	TXI	DC9	JT8D	T	B	1	C	5
03231040	OZA	DC9	JT8D	T	B	7	C	3
05201026	FAL	B737	JT8D	T	B	1	C	10
06231034	REP	DC9	JT8D	T	B	2	C	3
06241031	NWA	B727	JT8D	T	B	2	C	3
06241032	BNF	B727	JT8D	T	B	2	C	4
07071030	FAL	DC9	JT8D	T	B	2	C	4
07231032	ACL	B737	JT8D	T	B	2	NC	4
07301009	USA	DC9	JT8D	T	B	2	C	5
08211029	REP	DC9	JT8D	T	B	7	C	4
9141033	PSA	DC9	JT8D	T	B	7	C	4
10191031	BNF	B727	JT8D	T	B	2	C	4
10201030	REP	DC9	JT8D	T	B	7	C	3
10281025	ACL	B737	JT8D	T	B	1	C	3
11031016	MID	DC9	JT8D	T	B	7	C	3
11121025	FDE	B727	JT8D	T	B	7	NC	4
11131020	DAL	B727	JT8D	T	B	7	C	4
11231026	MID	DC9	JT8D	T	B	2	C	4
12091024	NWA	B727	JT8D	T	B	7	C	4

CHARACTERISTICS OF ROTOR FAILURES - 1981

SDR NO.	SUBMITTER	AIRCRAFT	ENGINE	COMPONENT	FRAGMENT TYPE	CAUSE	CONTAINMENT CONDITION	FLIGHT CONDITION
01191024	NWA	B727	JT8D	T	B	2	C	3
01261032	CAL	DC10	CF6	F	N	2	N	2
03101038	PAA	DC10	CF6	F	N	2	N	1
03031035	CAL	DC10	CF6	F	N	3	N	5
09161029	UAL	DC10	CF6	F	N	3	N	3
01191023	AFL	DC10	CF6	C	N	7	N	3
07211030	WRL	DC10	CF6	F	B	3	NC	4
06231033	UAL	DC10	CF6	C	B	1	C	5
07071029	AAL	DC10	CF6	C	B	3	C	6
05061026	PAA	DC10	CF6	T	B	2	C	4
04231029	UAL	DC10	CF6	T	B	2	C	2
04161034	WAL	DC10	CF6	T	B	1	C	5
07211029	UAL	DC10	CF6	T	B	2	C	4
07271030	CAL	DC10	CF6	T	B	7	C	4
10021027	PAA	DC10	CF6	T	R	7	C	4
10081033	PAA	DC10	CF6	T	B	7	C	5
10091029	AFL	DC10	CF6	T	D	3	NC	2
05131029	TIA	DC8	JT3D	F	N	3	N	4
04171033	UAC	DC8	JT3D	C	N	3	N	5
10021028	CAP	DC8	JT3D	C	N	3	N	2
06241028	SLD	DC8	JT3D	T	B	5	C	3
02231039	ILA	DC8	JT4A	T	N	7	N	5
03231039	ABX	SN601	JT15D	C	B	3	C	5
06181019	TWA	B747	JT9D	F	N	3	N	2
07161033	UAL	B747	JT9D	F	N	3	N	7
07421032	PAA	B747	JT9D	F	N	2	N	3
10131033	NWA	DC10	JT9D	C	N	3	N	5
10091031	FTL	B747	JT9D	F	B	1	NC	4
08171031	WRL	B747	JT9D	T	B	7	C	4
07171022	PAA	B747	JT9D	T	B	2	NC	3
01211012	NWA	B747	JT9D	T	B	1	C	3

THE FOLLOWING INCIDENCES DID NOT OCCUR IN THE UNITED STATES BUT INVOLVED U.S. REGISTERED AIRCRAFT SUBMITTED BY FAA

DATE	SUBMITTER	AIRCRAFT	ENG/ENG/SN	COMPONENT	FRAGMENT TYPE	CAUSE	CONTAINMENT CONDITION	FLIGHT CONDITION
1/31/81	NWA	DC10	JT9D/686165	F	B	7	NC	7
10/14/81	FTL	B747	JT9D/689156	T	B	2	NC	7
11/11/81	UNKNOWN	B747	JT9D/685764	F	B	3	NC	7
11/17/81	NWA	DC10	JT9D/618870	F	B	3	NC	7

CHARACTERISTICS OF ROTOR FAILURES - 1981

SDR NO.	SUBMITTER	AIRCRAFT	ENGINE	COMPONENT	FRAGMENT TYPE	CAUSE	CONTAINMENT CONDITION	FLIGHT CONDITION
10221033	TWA	L1011	RB211	C	N	6	N	5
08031030	TWA	L1011	RB211	T	N	2	N	4
06301030	EAL	L1011	RB211	F	B	3	C	3
04091034	TWA	L1011	RB211	C	B	1	C	4
05220124	EAL	L1011	RB211	C	B	1	C	5
10071024	TWA	L1011	RB211	C	B	1	C	4
11201028	EAL	L1011	RB211	C	B	2	C	5
02041034	EAL	L1011	RB211	C	B	2	C	4
08031031	TWA	L1011	RB211	T	B	7	C	4
08281032	DAL	L1011	RB211	T	B	2	NC	4
09231031	TWA	L1011	RB211	T	B	7	C	4
10161032	TWA	L1011	RB211	T	B	2	C	4
12021028	TWA	L1011	RB211	T	B	1	C	10
12151028	TWA	L1011	RB211	T	B	2	C	4
03041037	WRN	CL44	TYNE	C	N	7	N	5
08251032	SMB	CV600	DART	C	N	7	N	5
08121033	ZAN	G159	DART	F	N	1	N	5
03111032	PAI	YS11A	DART	T	N	2	N	2
02031034	RAM	STC24	DART	T	B	7	NC	10
03171040	SWT	FK27	DART	T	B	1	C	1
08271026	WRT	CV600	DART	T	B	2	C	2
08041014	USA	BA111	SPEY	C	N	3	N	3
10221032	USA	BA111	SPEY	C	R	7	C	4
11171028	RAN	FK28	SPEY	C	B	3	C	4
03111031	USA	BA111	SPEY	T	B	7	C	4
04031033	USA	BA111	SPEY	T	B	7	C	4
04031034	USA	BA111	SPEY	T	B	7	C	4
07071033	USA	BA111	SPEY	T	B	7	C	3
06261022	USA	BA111	SPEY	T	B	7	C	10
09241055	BRT	99	PT6A	C	B	3	C	2
07161038	PLG	99	PT6A	C	B	2	C	5
03251048	BRT	99	PT6A	T	B	7	C	5
02201052	BRT	99	PT6A	T	B	2	NC	5
10221031	RMA	DC7	PT6A	T	N	5	N	4
04201037	MTR	SD330	PT6A	T	N	2	N	1
10051058	AWA	DHC7103	PT6A	T	N	2	N	1
10201034	COH	SA226	TPE331	T	B	7	C	3
03161047	SUN	SA226	TPE331	T	B	7	C	3
04091048	RIO	SA226	TPE331	T	D	1	NC	2
11061030	RIO	SA226	TPE331	T	B	7	C	3
10221059	RIO	SA226	TPE331	T	B	7	C	5
10221060	RIO	SA226	TPE331	T	B	7	C	5
04211031	TIA	L382	501	C	N	3	N	3
06101030	FLA	L188	501	C	N	7	N	4
07241030	FLA	L188	501	C	N	7	N	2
11121024	TIA	L382	501	C	N	3	N	4

CHARACTERISTICS OF ROTOR FAILURES - 1981

SDR NO.	SUBMITTER	AIRCRAFT	ENGINE	COMPONENT	FRAGMENT TYPE	CAUSE	CONTAINMENT CONDITION	FLIGHT CONDITION
05061024	FIA	L188	501	C	N	3	N	4
08171030	REP	STCAP60	501	C	N	3	N	1
04061004	ISA	CV340	501	T	N	2	N	4
03191013	AIA	L382	501	T	B	2	C	2
03201019	AIA	L382	501	T	B	2	C	4
03271026	SRA	L382	501	T	B	7	C	1
03301036	SRA	L382	501	T	B	7	C	8
08211025	TIA	L382	501	T	B	2	NC	4
08261038	ALG	206	250C20	T	B	7	C	5

APPENDIX B

GAS TURBINE ENGINE FAILURE RATES ACCORDING TO ENGINE MODEL AND TYPE

MODEL	AVG NO. IN USE	ENGINE FLIGHT HOURS X10^6	NO. OF FAILURES				FAILURE RATES PER 10^6 ENGINE FLIGHT HRS.			
			C	NC	N	TOTAL	C	NC	N	TOTAL
TURBOFAN										
JT8D	4484	11.5	22	3	22	47	1.9	0.3	1.9	4.1
JT3D	958	1.64	1	0	3	4	0.6	0	1.8	2.4
JT9D	621	2.13	2	6	4	12	0.9	2.8	1.9	5.6
CF6	451	1.34	9	2	5	16	6.7	1.5	3.7	11.9
RB211	298	0.944	11	1	2	14	11.7	1.0	2.1	14.8
CF7	77	0.063	0	0	0	0	0	0	0	0
SPEY	70	0.148	7	0	1	8	47.3	0	6.8	54.1
JT15D	11	0.006	1	0	0	1	1.7	0	0	1.7
TFE731	4	0.001	0	0	0	0	0	0	0	0
ENG. TYPE TOTAL	6974	17.772	53	12	37	102	2.9	0.7	2.1	5.7
TURBOPROP										
PT6A	682	1.27	3	1	3	7	2.4	0.8	2.4	5.6
501	478	0.685	4	1	7	12	5.8	1.5	10.2	17.5
TPE331	229	0.45	5	1	0	6	11.1	2.2	0	13.3
DART	186	0.216	2	1	3	6	9.3	4.6	13.9	27.8
BASTAN	28	0.046	0	0	0	0	0	0	0	0
250B	19	0.021	0	0	0	0	0	0	0	0
TYNE	11	0.018	0	0	1	1	0	0	55.6	55.6
ENG. TYPE TOTAL	1633	2.706	14	4	14	32	5.2	1.5	5.2	11.8
TURBOSHAFT										
AST14	14	0.028	0	0	0	0	0	0	0	0
250C	4	0.0008	1	0	0	1	1250.0	0	0	1250.0
T58	1	0.0004	0	0	0	0	0	0	0	0
ENG. TYPE TOTAL	19	0.0292	1	0	0	1	34.2	0	0	34.2
TURBOJET										
JT4A	73	0.0351	0	0	1	1	0	0	28.5	28.5
AVON	6	0.002	0	0	0	0	0	0	0	0
ENG. TYPE TOTAL	79	0.0371	0	0	1	1	0	0	27.0	27.0

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